

Development of Physics-Based Numerical Models for Uncertainty Quantification of Selective Laser Melting Processes

Completed Technology Project (2015 - 2018)



Project Introduction

The goal of the proposed research is to characterize the influence of process parameter variability inherent to Selective Laser Melting (SLM) and performance effect on components manufactured with the SLM technique for space flight systems. Specific objectives are: To develop, verify, and validate robust physics-based numerical models for predictive SLM simulation using a DOE multi-physics, multi-scale massively parallel code called ALE3D for powder-scale SLM process simulations. To quantify the uncertainty in the prediction of material density and maximum tensile residual stress during laser melting and solidification of cubic coupons. A synergistic computational and experimental approach is proposed. The team assembled for this project includes J-P Delplanque (PI) and E. J. Lavernia (co-I) at UC Davis and collaborators R. McCallen, A. Anderson, and C. Kamath at Lawrence Livermore National Laboratory. The approach focuses on the melt-pool/powder-scale phenomena. A simple configuration (single track and cubic coupons) is considered. An uncertainty quantification strategy will be developed using PSUADE (LLNL) and surrogate models. Quantities of interest are: density and maximum tensile residual stress. ALE3D (LLNL) will be used to perform detailed numerical simulations. Laser melting experiments will be conducted to validate detailed numerical simulations and a surrogate process model will be developed on the basis of detailed numerical simulations. An important outcome will be a path to predictive numerical simulation of SLM processes and the identification of strategies to mitigate part variability. It is noted that the development of the surrogate model will also provide insight and guidance for the future development of reduced-order models and, in the longer term, process control strategies. The validation and uncertainty quantification methodology developed will be relevant to other additive manufacturing technologies (e.g., Direct Laser Deposition). The proposed work will constitute a cornerstone of the improved understanding of uncertainty quantification of the SLM process needed for the certification of components produced by these techniques. The proposed work will benefit from active collaborations between UCD, LLNL, and NASA ARC. Geographic proximity will facilitate regular meetings and provide ample opportunities for information exchange to ensure that the research is consistent with NASA's needs and that it benefits from and complements ongoing efforts at NASA and LLNL. Existing collaboration between UC Davis and LLNL in the context of Accelerated Certification of the Additively Manufactured Metals initiative at LLNL will be leveraged. The proposed work directly addresses subtopic 2(a) of the solicitation (Uncertainty quantification for additive manufacturing). Since the outcomes will contribute to the development of model-based certification methods the proposed research is pertinent to Technology Area 12 (Materials, Structures, Mechanical Systems and Manufacturing) of NASA's Space Technology Roadmaps.

Anticipated Benefits

This work constitutes a cornerstone of the improved understanding of



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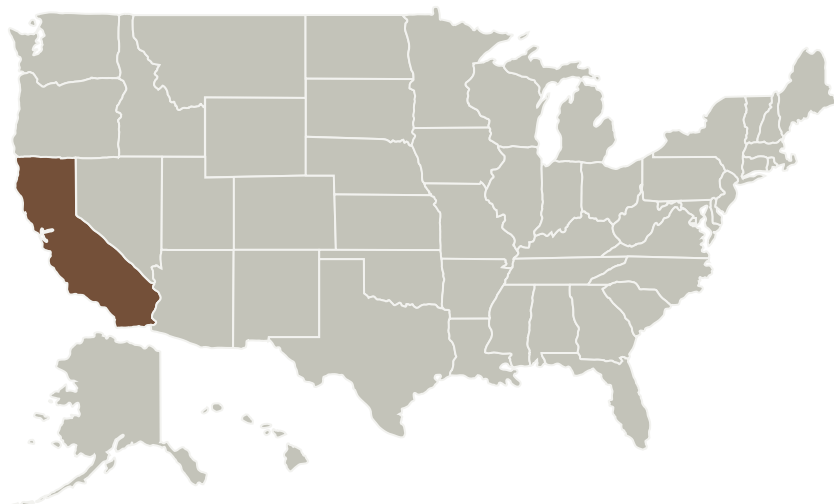
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uncertainty quantification of the SLM process needed for the certification of components produced by these techniques.

Primary U.S. Work Locations and Key Partners



Organizations Performing Work	Role	Type	Location
University of California-Davis(UC Davis)	Lead Organization	Academia Asian American Native American Pacific Islander (AANAPISI)	Davis, California

Primary U.S. Work Locations

California

Project Website:

<https://www.nasa.gov/directorates/spacetech/home/index.html>

Organizational Responsibility

Responsible Mission Directorate:

Space Technology Mission Directorate (STMD)

Lead Organization:

University of California-Davis (UC Davis)

Responsible Program:

Space Technology Research Grants

Project Management

Program Director:

Claudia M Meyer

Program Manager:

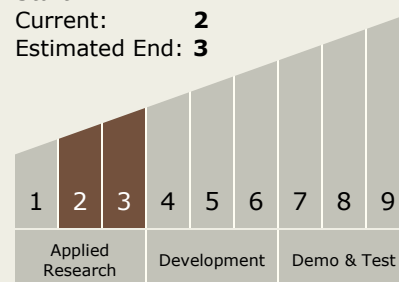
Hung D Nguyen

Principal Investigator:

Jean-pierre Delplanque

Technology Maturity (TRL)

Start: 2
Current: 2
Estimated End: 3



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Technology Areas

Primary:

- TX09 Entry, Descent, and Landing
 - └ TX09.4 Vehicle Systems
 - └ TX09.4.5 Modeling and Simulation for EDL

Target Destination

Foundational Knowledge